
Requake

Release 0.6

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May 06, 2024

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Repeating earthquakes search and analysis.

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DESCRIPTION

Requake is a command line tool to search and analyse repeating earthquakes.

It can either scan an existing earthquake catalog to search for similar events, or perform template matching on a continuous waveform stream.

Catalogs and waveforms can be read from local files or downloaded using standard [FDSN web services](#).

Requake is written in Python and uses [ObsPy](#) as backend.

1.1 Installation

1.1.1 Installing the latest release

Using pip and PyPI (preferred method)

The latest release of Requake is available on the [Python Package Index](#).

You can install it easily through pip:

```
pip install requake
```

1.1.2 Installing a development snapshot

If you need a recent feature that is not in the latest release (see the `unreleased` section in the [Requake Changelog](#)), you want to use the more recent development snapshot from the [Requake GitHub repository](#).

Using pip

The easiest way to install the most recent development snapshot is to download and install it through pip, using its builtin git client:

```
pip install git+https://github.com/SeismicSource/requake.git
```

Run this command again, from times to times, to keep Requake updated with the development version.

Cloning the Requake GitHub repository

If you want to take a look at the source code (and possibly modify it), clone the project using `git`:

```
git clone https://github.com/SeismicSource/requake.git
```

or, using SSH:

```
git clone git@github.com:SeismicSource/requake.git
```

(avoid using the “Download ZIP” option from the green “Code” button, since version number is lost).

Then, go into the `requake` main directory and install the code in “editable mode” by running:

```
pip install -e .
```

You can keep your local Requake repository updated by running `git pull` from times to times. Thanks to `pip`’s “editable mode”, you don’t need to reinstall Requake after each update.

1.2 Running

1.2.1 Command line arguments

Requake is based on a single executable, aptly named `requake` .

To get help, use:

```
requake -h
```

Different commands are available:

<code>sample_config</code>	write sample config file to current directory and exit
<code>update_config</code>	update an existing config file to the latest version
<code>read_catalog</code>	read an event catalog from web services or from a file
<code>print_catalog</code>	print the event catalog to screen
<code>scan_catalog</code>	scan an existing catalog for earthquake pairs
<code>print_pairs</code>	print pairs to screen
<code>plot_pair</code>	plot traces for a given event pair
<code>build_families</code>	build families of repeating earthquakes from a catalog of pairs
<code>print_families</code>	print families to screen
<code>plot_families</code>	plot traces for one ore more event families
<code>plot_timespans</code>	plot family timespans
<code>plot_cumulative</code>	cumulative plot for one or more families
<code>map_families</code>	plot families on a map
<code>flag_family</code>	flag a family of repeating earthquakes as valid or not valid.
<code>build_templates</code>	build waveform templates for one or more event families
<code>scan_templates</code>	scan a continuous waveform stream using one or more templates

Certain commands (e.g., `plot_pair`) require further arguments (use, e.g., `requake plot_pair -h` to get help).

Requake supports command line tab completion for commands and arguments, thanks to [argcomplete](#). To enable command line tab completion, add the following line to your `.bashrc` or `.zshrc`:

```
eval "$(register-python-argcomplete requake)"
```

1.2.2 Typical workflow

The first thing you will want to do is to generate a sample *Configuration File*:

```
requake sample_config
```

Edit the *Configuration File* according to your needs, then read or download the event catalog:

```
requake read_catalog
```

or

```
requake read_catalog CATALOG_FILE
```

Now, build the catalog of event pairs with:

```
requake scan_catalog
```

Once done (*it will take time!*), you are ready to build repeating earthquake families:

```
requake build_families
```

1.3 Performances

- `requake scan_catalog` took 53 minutes on my 2.7 GHz i7 MacBook Pro to process 14,100,705 earthquake pairs. Downloaded traces are cached in memory to speed up execution. Processing is not yet parallel: some improvements might come in future versions, when parallelization will be implemented.
- `requake build_families` is fast™.

1.4 Slip Models

Following Uchida [2019], Requake provides different models to estimate fault slip (or creep) from repeating earthquakes magnitude.

First of all, magnitude is converted to seismic moment using the well known formula of Hanks and Kanamori [1979] (seismic moment M_0 in):

$$M_0 = 10^{1.5(M_w + 6.07)}$$

or (seismic moment M_0 in):

$$M_0 = 10^{1.5(M_w + 10.7)}$$

Then, slip is estimated using one of the three models discussed below, selectable using the `mag_to_slip_model` parameter in the *Configuration File*. See **Figure 1** for a comparison of the three models.

Fig. 1: **Figure 1** Relationship between magnitude (or seismic moment) and slip for three models. Figure from Uchida [2019].

1.4.1 Nadeau and Johnson (1998)

Nadeau and Johnson [1998] proposed the following empirical relationship between the seismic moment of a repeating earthquake (M_0 in) and the fault slip around it (d in):

$$d = 10^{-2.36} M_0^{0.17}$$

This formula is selected by setting the `mag_to_slip_model` parameter to N1998.

1.4.2 Beeler et al. (2001)

Beeler *et al.* [2001] proposed an alternative empirical model to explain the recurrence intervals of the Parkfield repeaters, which accounts for the possibility of aseismic slip around the repeating earthquakes asperities. In this model the repeating earthquake asperity is allowed to continuously creep and strain harden until reaching a failure threshold stress. Their model for fault slip d (in) is the following:

$$d = \Delta\sigma \left[\frac{1}{1.81\mu} \left(\frac{M_0}{\Delta\sigma} \right)^{\frac{1}{3}} + \frac{1}{C} \right]$$

where $\Delta\sigma$ is the static stress drop (in), μ is the rigidity (in), M_0 is the seismic moment (in), and C is the strain hardening coefficient (in).

This formula is selected by setting the `mag_to_slip_model` parameter to B2001. The values for static stress drop, rigidity and strain hardening coefficient must be set in the [Configuration File](#).

1.4.3 Eshelby (1957) circular crack model

A somehow simpler approach is to assume that the fault creep around the repeater asperity is equal to the slip released by the repeater rupture. Assuming a circular crack with constant stress-drop, one can derive the slip (d , in) as:

$$d = \frac{M_0}{\pi\mu a^2}$$

where M_0 is the seismic moment (in), μ is the rigidity (in) and a is the fault radius (in).

The source radius (in) is obtained from the Eshelby [1957] formula:

$$a = \left(\frac{7}{16} \frac{M_0}{\Delta\sigma} \right)^{\frac{1}{3}}$$

Where $\Delta\sigma$ is the static stress drop (in).

This formula is selected by setting the `mag_to_slip_model` parameter to E1957. The value for static stress drop must be set in the [Configuration File](#).

1.5 Configuration File

Configuration file (default name: `requake.conf`) is a plain text file with keys and values in the form `key = value`. Comment lines start with `#`.

Here is the default config file, generated through `requake sample_config`:

```
#### Configuration file for Requake

#### Station metadata and waveform data
## FDSN station webservice URL to retrieve station metadata.
## Use a full URL or a ObsPy shortcut (e.g., IRIS, RESIF, GEOFON, ...)
fdsn_station_url = http://example.com
## Alternatively, you can provide the path to a local file with station
## metadata in any format supported by ObsPy (note that some formats may not
## contain station coordinates, which are required for the scan,
## see https://docs.obspy.org/packages/obspy.core.inventory.html).
## If both fdsn_station_url and stationxml_file are provided, the
## local file will be used.
station_metadata_path = None
## FDSN datasetselect webservice URL to retrieve waveforms.
## Use a full URL or a ObsPy shortcut (e.g., IRIS, RESIF, GEOFON, ...)
fdsn_datasetselect_url = http://example.com
## Alternatively, you can provide the path to a local SDS waveform archive
## (see https://docs.obspy.org/packages/autogen/obspy.clients.filesystem.sds.html)
waveform_data_path = None

#### Catalog-based scan
#### The following parameters are for a catalog-based scan:
#### each catalog event is compared with the other catalog events within
#### a certain distance range. Similarity is checked by waveform
#### cross-correlation at one or more stations.
#### To perform a catalog-based scan use:
####     requake scan_catalog
## FDSN event webservice URL to retrieve event catalogs.
## Use a full URL or a ObsPy shortcut (e.g., IRIS, RESIF, GEOFON, ...)
catalog_fdsn_event_url = http://example.com
## start time for event selection (UTC date time)
catalog_start_time = 2021-08-23T00:00:00
## end time for event selection (UTC date time or 'now')
catalog_end_time = 2021-08-24T00:00:00
## Optionally, up to three other sources can be defined for different
## time intervals
catalog_fdsn_event_url_1 = None
catalog_start_time_1 = None
catalog_end_time_1 = None
catalog_fdsn_event_url_2 = None
catalog_start_time_2 = None
catalog_end_time_2 = None
catalog_fdsn_event_url_3 = None
catalog_start_time_3 = None
catalog_end_time_3 = None
## geographic selection (decimal degrees)
```

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```

catalog_lat_min = 12.5
catalog_lat_max = 18.5
catalog_lon_min = -62.5
catalog_lon_max = -58.5
## depth selection (km, positive down)
catalog_depth_min = 0
catalog_depth_max = 60
## magnitude selection
catalog_mag_min = 2
catalog_mag_max = 4
## maximum distance range to search for similar earthquakes (radius, km)
catalog_search_range = 30
## trace id(s) to compute cross-correlation, in NET.STA.LOC.CHAN format.
## Waveform data for this trace(s) id will be retrieved using the station
## webservice.
## If more than a trace_id is specified (separated by commas), the closest
## station will be used for a given event pair.
catalog_trace_id = NET.STA.LOC.CHAN

##### Template-based scan
### The following parameters are for template-based scan:
### A template is used to search for similar waveforms at a given station
### over a givent time interval.
### To perform a template-based scan use:
###   requake scan_templates
## start time for template search (UTC date time)
template_start_time = 2021-08-23T00:00:00
## end time for event template search (UTC date time or 'now')
template_end_time = 2021-08-24T00:00:00
## Time chunk (in seconds) to analyze continuous data.
## Large values (1 hour or more) will result in fewer data requests and
## faster execution. However, cross-correlation can be slow for too large
## values. No more than one event per time chunk can be detected, so the
## length of time chunk should be smaller than the minimum inter-event time
## you want to detect.
time_chunk = 3600
## Overlap between time chunks (in seconds)
time_chunk_overlap = 60
## Minimum ratio between cross-correlation (cc) and median absolute deviation
## (MAD) of cross-correlation (cc_mad). A detection id declared when:
##   cc/cc_mad > min_cc_mad_ratio
min_cc_mad_ratio = 50

##### Processing parameters
## Seconds before P arrival to cut trace (only used for catalog search)
cc_pre_P = 5
## Trace length in seconds (only used for catalog search)
cc_trace_length = 120
## Frequency range for computing cross-correlation (Hz)
cc_freq_min = 2
cc_freq_max = 10
## Maximum authorized shift for computing cross-correlation (s)

```

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```

cc_max_shift = 5
## Minimum cross-correlation value to declare similar waveforms
## (between 0 and 1)
cc_min = 0.95
## Clustering algorithm to create families of similar events.
## Possible options are:
##   shared : families are created by clustering all event pairs sharing
##             an event
##   UPGMA : families are created through the Unweighted Pair Group Method
##           with Arithmetic Mean (UPGMA) algorithm
##           (see https://en.wikipedia.org/wiki/UPGMA)
clustering_algorithm = shared
## Search for anticorrelated events (negative CC)
cc_allow_negative = false
## How families should be sorted when assigning family numbers.
## Possible options are:
##   time : increasing origin time of first event in family (default option)
##   longitude : increasing longitude
##   latitude : increasing latitude
##   depth : increasing depth
##   distance_from : increasing horizontal distance from a given point
sort_families_by = time
## Longitude and latitude of reference point,
## if sort_families_by = 'distance_from'
distance_from_lon = None
distance_from_lat = None
## Templates are built by averaging the traces in the family.
## Set the following parameter to True if you want to normalize the traces
## before averaging.
## Normalization will produce an average trace which is more representative
## of the family, but will be less effective in reducing noise.
normalize_traces_before_averaging = False

#### Post-processing parameters
## Estimation of fault slip (in cm) from repetater's magnitude
## Choose between:
##   NJ1998 : Nadeau and Johnson (1998)
##   B2001 : Beeler et al. (2001)
##   E1957 : Eshelby (1957), circular crack model
## See Uchida (2019, https://doi.org/10.1186/s40645-019-0284-z) for details
## on the models.
mag_to_slip_model = NJ1998
## Static stress drop value for B2001 and E1957 models (MPa)
static_stress_drop = 10.0
## Rigidity value for B2001 and E1957 models (GPa)
rigidity = 30.0
## Strain hardening coefficient for B2001 model (MPa/cm)
strain_hardening = 0.5

```

1.6 Requake Changelog

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1.6.1 v0.6 - 2024-05-04

Note: you might want to run `requake update_config` to update your config file to the latest version.

- Verb `plot_slip` renamed to `plot_cumulative`. This new verb has new options to plot cumulative slip, cumulative moment, and cumulative number of events, and to make the plot logarithmic.
- New verb `print_catalog`: print the event catalog to screen
- New verb `print_pairs`: print the event pairs to screen
- `print_families`: also print minimum and maximum family magnitudes
- Additional models to convert magnitude to slip. Currently supported models are: Nadeau and Johnson (1998), Beeler et al. (2001), Eshelby (1957). Model selection is done using the `mag_to_slip_model` config parameter.
- New verb `update_config`: update an existing config file to the latest version

1.6.2 v0.5 - 2024-04-23

- New config options: `station_metadata_path` and `waveform_data_path` to read station metadata and waveform data from files. Supports any metadata format supported by ObsPy and SDS (SeisComp Data Structure) waveform archives.
- Filter catalog files on reading using the criteria in the config file
- Improved time axes in `plot_timespans` and `plot_slip` for short time intervals
- `print_families`: autoset duration units based on the average duration
- `plot_timespans`: default sorting changed to `family_number`

1.6.3 v0.4.1 - 2024-03-11

- Bugfix: `requake` executable was not installed

1.6.4 v0.4 - 2024-03-11

- Package license changed to GPL-3.0 or later
- New verb: `read_catalog`: read a catalog from web services or from a file (FDSN text, QuakeML, or CSV)
- New verb: `scan_templates`: scan a continuous waveform stream using one or more templates. Templates can be from families or from file
- New verb: `print_families`: print families to screen
- New verb: `plot_slip`: plot cumulative slip for one or more families
- New config parameter: `clustering_algorithm` to select the algorithm for building event families. Currently supported options are `shared` and `UPGMA` (default: `shared`)
- `family_numbers` argument is no more mandatory (default: `all`)

- argument added to `map_families` and `plot_timespans`
- Config parameter `trace_average_from_normalized_traces` renamed to `normalize_traces_before_averaging`
- `plot_timespans`: possibility to sort by `family_number`
- New options for `map_families` to select a map style and a zoom level for the map tiles
- New option `--minevents (-m)` for many verbs, to select families with a minimum number of events
- Support for events with no location
- Bugfix: `plot_timespans`: correctly plot x time axis when sort by time

1.6.5 v0.3 - 2021-11-08

- New verb: `build_templates`
- New option: `cc_allow_negative` to search for anticorrelated events
- New progressbar, using `tqdm`
- `plot_families`:
 - show average trace
 - pan/zoom traces using arrows
 - show/hide theoretical arrivals using ‘a’ (command line option removed)
 - show event origin time as y-label
 - show trace mean CC
 - also shift theoretical arrivals when aligning traces
- Bugfix: last family was not read from family file

1.6.6 v0.2 - 2021-09-24

Mostly a bugfix release with a slightly improved trace plotting.

- Bugfix: `scan_catalog` could not run properly due to missing variable
- Bugfix: detrend traces before filtering
- `plot_families`: print number of events and station-event distance

1.6.7 v0.1 - 2021-09-16

- Initial release, not yet feature complete

1.7 How to Cite

If you used Requake for a scientific paper, please cite it as:

Satriano, C. (2024). Requake: Repeating earthquakes search and analysis (X.Y). doi: [10.5281/ZENODO.10832204](https://doi.org/10.5281/ZENODO.10832204)

Please replace X.Y with the Requake version number you used.

You can also cite the following abstract presented at the 2016 AGU Fall Meeting:

Satriano, C., Doucet, A. & Bouin, M.-P. (2021). Probing the creep rate along the Lesser Antilles Subduction Zone through repeating earthquakes. In AGU Fall Meeting Abstracts (Vol. 2021, pp. T25A-0167), bibcode: [2021AGUFM.T25A0167S](https://ui.adsabs.org/2021AGUFM.T25A0167S)

1.8 References

- [genindex](#)
- [modindex](#)
- [search](#)

BIBLIOGRAPHY

- [1] Naoki Uchida. Detection of repeating earthquakes and their application in characterizing slow fault slip. *Progress in Earth and Planetary Science*, May 2019. doi:10.1186/s40645-019-0284-z.
- [2] Thomas C. Hanks and Hiroo Kanamori. A moment magnitude scale. *Journal of Geophysical Research: Solid Earth*, 84(B5):2348–2350, May 1979. doi:10.1029/jb084ib05p02348.
- [3] Robert M. Nadeau and Lane R. Johnson. Seismological studies at parkfield vi: moment release rates and estimates of source parameters for small repeating earthquakes. *Bulletin of the Seismological Society of America*, 88(3):790–814, June 1998. doi:10.1785/bssa0880030790.
- [4] N. M. Beeler, D. L. Lockner, and S. H. Hickman. A simple stick-slip and creep-slip model for repeating earthquakes and its implication for microearthquakes at parkfield. *Bulletin of the Seismological Society of America*, 91(6):1797–1804, December 2001. doi:10.1785/0120000096.
- [5] J D Eshelby. The determination of the elastic field of an ellipsoidal inclusion, and related problems. *Proc. R. Soc. Lond.*, 241(1226):376–396, August 1957. doi:10.1098/rspa.1957.0133.